the
meteorological
magazine

551.507.352:551.515.827

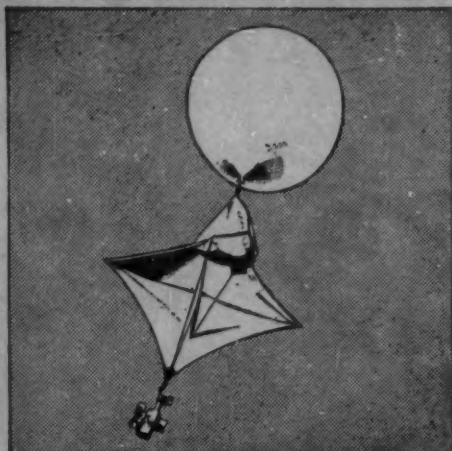## TEMPERATURE AND HUMIDITY FLUCTUATIONS IN A DRY FRONTAL ZONE

By D. R. GRANT

Summary.—Examples are given of some continuous records of fluctuations of indicated temperature, vapour pressure and vertical velocity along a series of horizontal flight paths near the boundary of two air masses ; vertical cross-sections of temperature and dew-point are also shown.

Within the transition zone patches of air existed with well-defined boundaries and the sources of the patches could be identified by their wet-bulb potential temperature. The types of air present in various zones were plotted on a vertical cross-section. It appears that there was mixing of patches on a relatively large scale but that the boundaries of the patches remained sharp because the small-scale mixing was very slow.

Introduction.—In a recent article[1] in the *Meteorological Magazine* some wave-like variations in the height of the isentropic surfaces in an inversion layer were described. Further flights have been made in an attempt to find other examples of regular wave motion, but without success. In one of these flights, however, some remarkably large irregular variations of humidity were found, and subsequent analysis showed that they were apparently occurring at the boundary between two air masses. The magnitude of the fluctuations was enhanced by the fact that the air below the transition zone was very dry air associated with a subsidence inversion. The measurements indicated that the mixing was very incomplete.

The flight was made on 11 May 1965 between 0930 and 1330 GMT about 20 miles west of Farnborough, Hampshire. An anticyclone was centred over south-east England. A weak warm front was almost stationary over the west of England and was being frontolysed. The flight consisted of an ascent to obtain a temperature and humidity sounding, followed by a number of level runs at different heights (on headings of 055° or 235°) within the isothermal layer and roughly perpendicular to the warm front, and finally another sounding. In the level runs which were about 27 nautical miles long, frequent observations were made of temperature and dew-point and continuous records were obtained of fluctuations of indicated temperature (i.e. temperature not corrected for the speed of the aircraft), vapour pressure and the vertical velocity of the air with rapidly responding instruments. A measurement of mean wind at each level was also made. The instruments used have been described by Grant[2] in a previous article.

The observations.—The temperature and humidity soundings made over Farnborough before and after the level runs are shown in Figure 1. The

33

THE METEOROLOGICAL MAGAZINE

551.507.352:551.515.827

TEMPERATURE AND HUMIDITY FLUCTUATIONS IN A DRY FRONTAL ZONE

By D. R. GRANT

Summary.—Examples are given of some continuous records of fluctuations of indicated temperature, vapour pressure and vertical velocity along a series of horizontal flight paths near the boundary of two air masses ; vertical cross-sections of temperature and dew-point are also shown.

Within the transition zone patches of air existed with well-defined boundaries and the sources of the patches could be identified by their wet-bulb potential temperature. The types of air present in various zones were plotted on a vertical cross-section. It appears that there was mixing of patches on a relatively large scale but that the boundaries of the patches remained sharp because the small-scale mixing was very slow.

Introduction.—In a recent article[1] in the *Meteorological Magazine* some wave-like variations in the height of the isentropic surfaces in an inversion layer were described. Further flights have been made in an attempt to find other examples of regular wave motion, but without success. In one of these flights, however, some remarkably large irregular variations of humidity were found, and subsequent analysis showed that they were apparently occurring at the boundary between two air masses. The magnitude of the fluctuations was enhanced by the fact that the air below the transition zone was very dry air associated with a subsidence inversion. The measurements indicated that the mixing was very incomplete.

The flight was made on 11 May 1965 between 0930 and 1330 GMT about 20 miles west of Farnborough, Hampshire. An anticyclone was centred over south-east England. A weak warm front was almost stationary over the west of England and was being frontolysed. The flight consisted of an ascent to obtain a temperature and humidity sounding, followed by a number of level runs at different heights (on headings of 055° or 235°) within the isothermal layer and roughly perpendicular to the warm front, and finally another sounding. In the level runs which were about 27 nautical miles long, frequent observations were made of temperature and dew-point and continuous records were obtained of fluctuations of indicated temperature (i.e. temperature not corrected for the speed of the aircraft), vapour pressure and the vertical velocity of the air with rapidly responding instruments. A measurement of mean wind at each level was also made. The instruments used have been described by Grant[2] in a previous article.

The observations.—The temperature and humidity soundings made over Farnborough before and after the level runs are shown in Figure 1. The
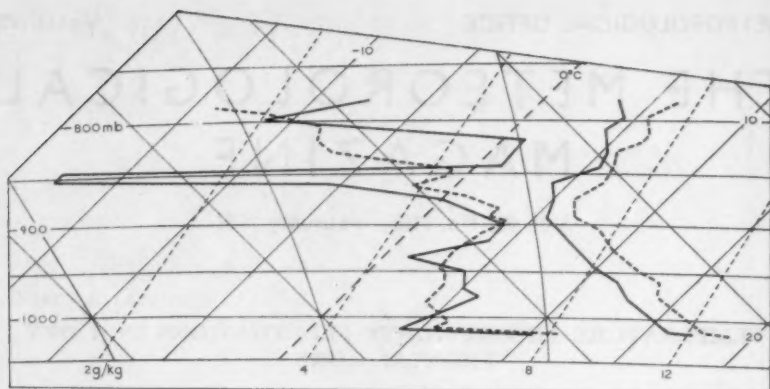
FIGURE 1—TEMPERATURE AND DEW-POINT SOUNDINGS AT START AND END OF
FLIGHT

——— First ascent, 0937 to 0958 GMT.
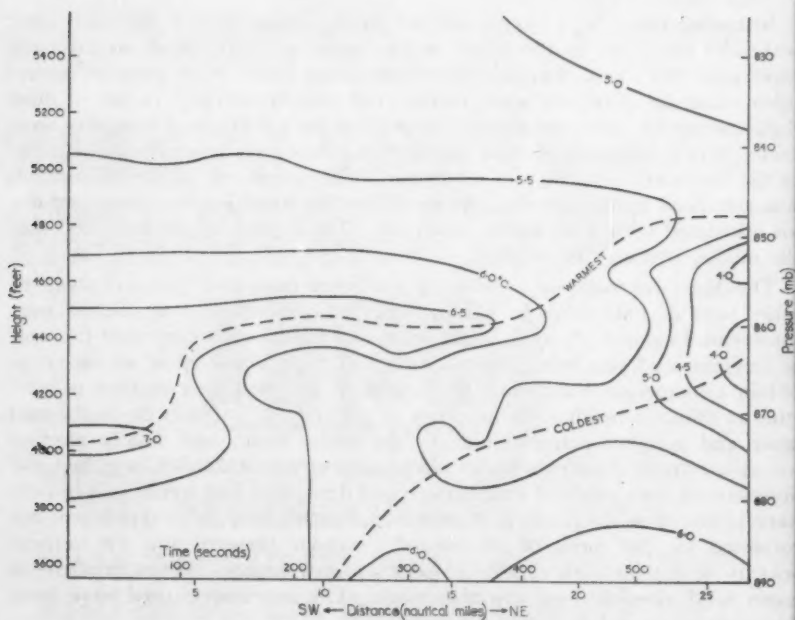- - - Second ascent, 1311 to 1326 GMT.

FIGURE 2—VERTICAL CROSS-SECTION OF TEMPERATURE
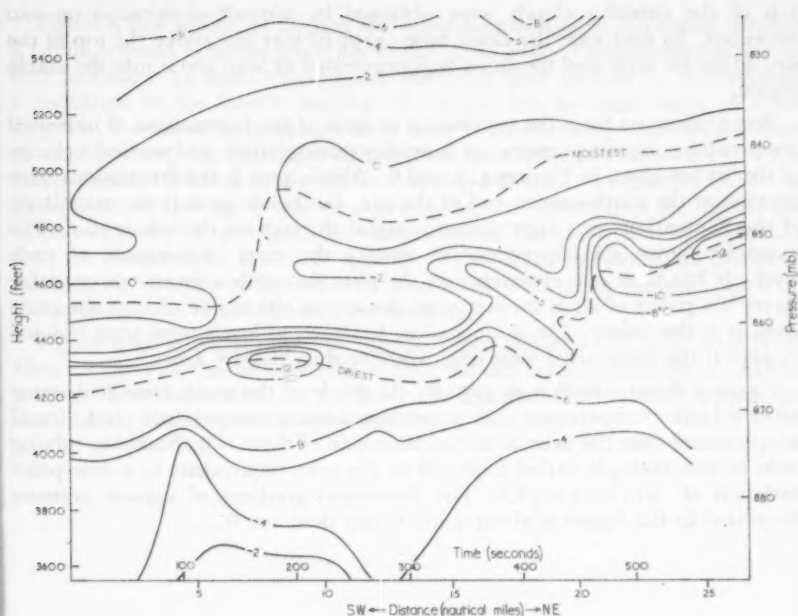Isopleths at intervals of ½ degC.

34

FIGURE 3—VERTICAL CROSS-SECTION OF DEW-POINT
Isopleths at intervals of 2 degC.

time interval between the ascents was about three and a half hours. Up to 900 mb (3200 ft) the lapse rates were almost dry adiabatic and warming had taken place during the flight at all levels. Vertical cross-sections of temperature and dew-point drawn from the observations taken on the level runs (Figures 2 and 3) show that to the north-east the coldest air was at a height of 4350 ft, whereas at the south-western end of the runs it was below 3600 ft. Part of this difference may have been due to advection as the coldest air was examined in the south-western area about 50 minutes later than in the north-eastern area. Winds were constant at 210° 7 kt from the surface up to about 4000 ft and veered at higher levels to 290° 7 kt at 5500 ft. Allowing for a movement at a mean wind speed of 7 kt, the slope of the surface in which the air was coldest must have been about 1:270. The heights at which the warmest air was found (Figure 2) and the heights of the dry and moist layers (Figure 3) had a similar slope. As observations over the whole section took about three hours to complete and the highest levels were flown first, the continuous warming which was taking place (as shown in Figure 1) resulted in the temperatures at the lowest level in the cross-section being about 1 degC warmer than they were at the time the top level was flown.

Cloud amounts reported by Farnborough at the times of the level runs were 4/8 cumulus becoming, towards the end of the period, 2/8 cumulus and 4/8 stratocumulus. The amount of cloud was much less than this at the south-western end of the runs. Accurate measurements of the heights of the base and

35

top of the cumulus clouds were obtained by aircraft observation on two occasions. In each case the cloud base (4050 ft) was just above the top of the dry adiabatic layer and the cloud tops penetrated at least 400 ft into the stable region.

Some examples from the continuous records of the fluctuations of indicated temperature, vapour pressure (or humidity mixing ratio) and vertical velocity of the air are given in Figures 4, 5 and 6. Above 4400 ft the fluctuations were greatest at the north-eastern end of the run, but below 4400 ft the magnitude of the fluctuations was approximately equal throughout the whole run. The examples shown for illustration are usually the most pronounced at each level. It has been our experience in the past that within inversions or stable layers if a patch of air is moister than the air on either side of it at the same level, it is also colder. On this occasion, however, at levels from 5050 ft down to 4050 ft the moist areas were often warmer than the dry areas.

Figure 4 shows a section at 4750 ft. At this level the moist areas had some-times a higher temperature and sometimes a lower temperature (and virtual temperature) than the drier areas on either side of them. The humidity mixing ratio in this example varied from 0·8 to 4·7 g/kg (equivalent to a dew-point variation of −21 to +0·5°C). The horizontal gradient of vapour pressure illustrated in this figure is about 3 mb in less than 100 ft.

FIGURE 4—INDICATED TEMPERATURE, VAPOUR PRESSURE AND VERTICAL AIR VELOCITY FLUCTUATIONS AT 4750 FT

——————— Vertical air velocity,
– – – Temperature,
–·–·–·– Vapour pressure and humidity mixing ratio.

Figure 5 is a section at 4550 ft and gives an example of a traverse through a cumulus cloud at about 500 ft above the cloud base. The indicated temperature was about $3\frac{1}{2}$ degC colder inside the cloud than outside it. Allowing for a reduction in the kinetic heating of 1 degC due to evaporation of cloud droplets, the cloud temperature must have been about $2\frac{1}{2}$ degC colder than its environment, i.e. the cloud temperature must have been about 3°C. The rise in vapour pressure of 4·5 mb on entering the cloud is equivalent to a rise in dew-point from −12°C (the dew-point measured in the clear air outside the cloud) to +2·5°C, giving almost saturation in the cloud and so indicating that the observations are fairly reliable. Apart from the cloud, all the moist air at this level was warmer than the dry, but at some other places at this level the moist air was colder than its surroundings.

Figure 6 gives an example at 3550 ft, about 500 ft below cloud base level. Here all the moist areas were colder than the dry areas around them. At this level the mean lapse rate was probably still less than dry adiabatic despite the fact that the cloud base was 500 ft above.
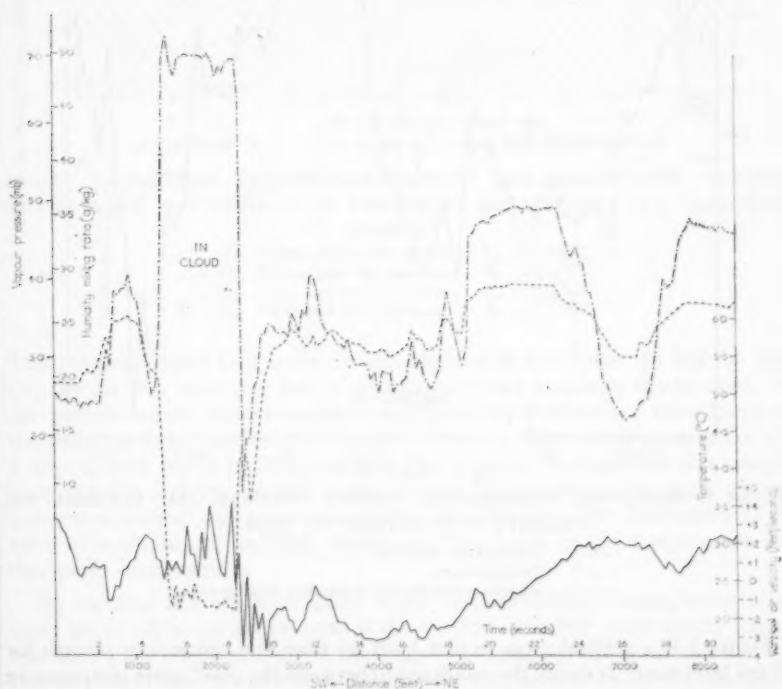
FIGURE 5—INDICATED TEMPERATURE, VAPOUR PRESSURE AND VERTICAL AIR VELOCITY FLUCTUATIONS AT 4550 FT INCLUDING A CUMULUS CLOUD TRAVERSE

——————— Vertical air velocity,
– – – Temperature,
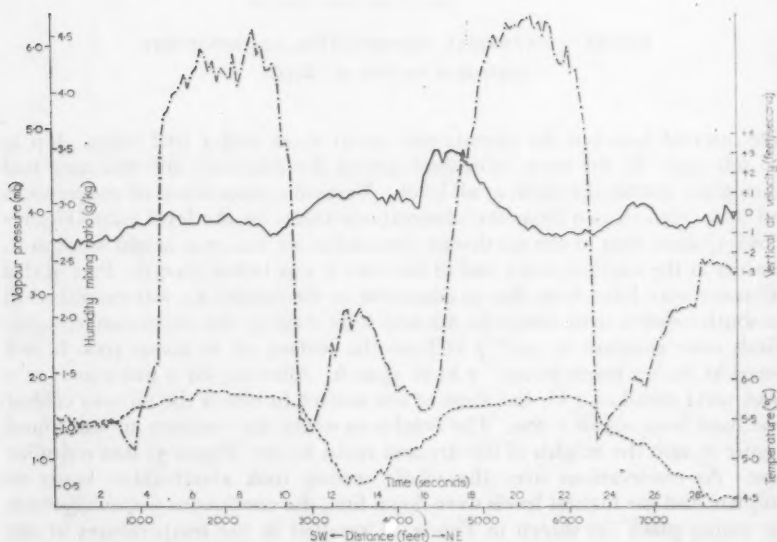—·—·—·— Vapour pressure and humidity mixing ratio.

37
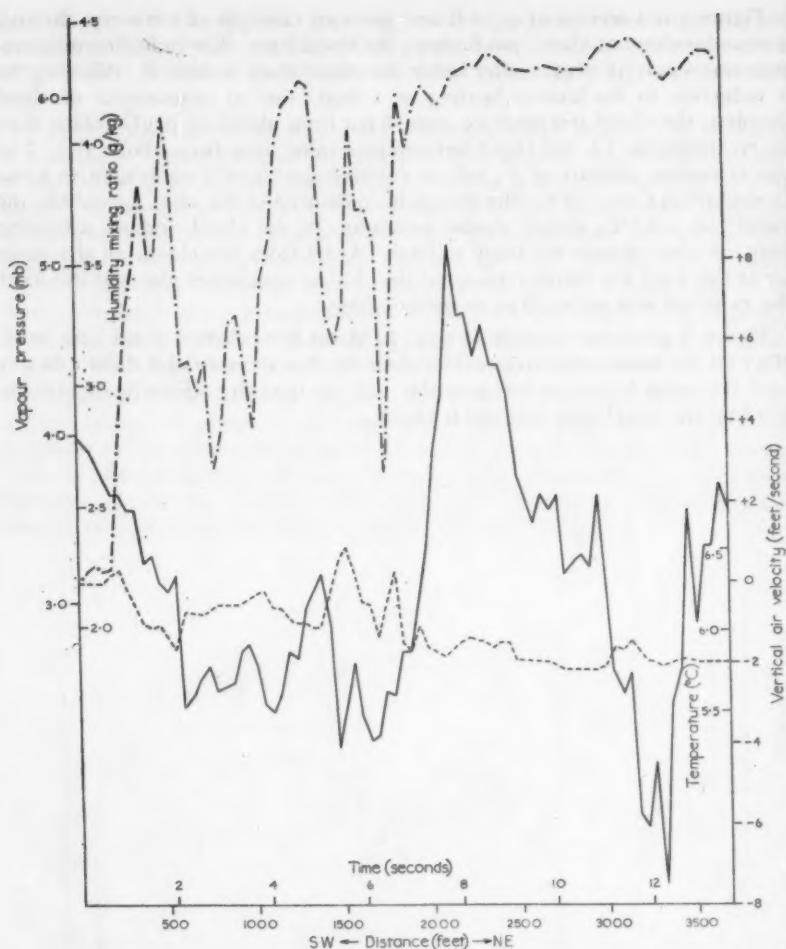
FIGURE 6—INDICATED TEMPERATURE, VAPOUR PRESSURE AND VERTICAL AIR VELOCITY FLUCTUATIONS AT 3550 FT

———— Vertical air velocity,
— — — Temperature,
—·—·— Vapour pressure and humidity mixing ratio.

Figure 7 is a vertical cross-section built up from the continuous records for all the level runs. It shows the relationship between the small-scale temperature and humidity fluctuations of the air, e.g. 'W_m' means that the warm patches in that area were moister than the colder air around them at the same level. The wet-bulb potential temperatures (θ_w) at the upper levels are values representative of the air at the places indicated. The wet-bulb potential temperatures of the patches of air at lower levels are extreme values which were frequently encountered although intermediate values were also obtained.

38
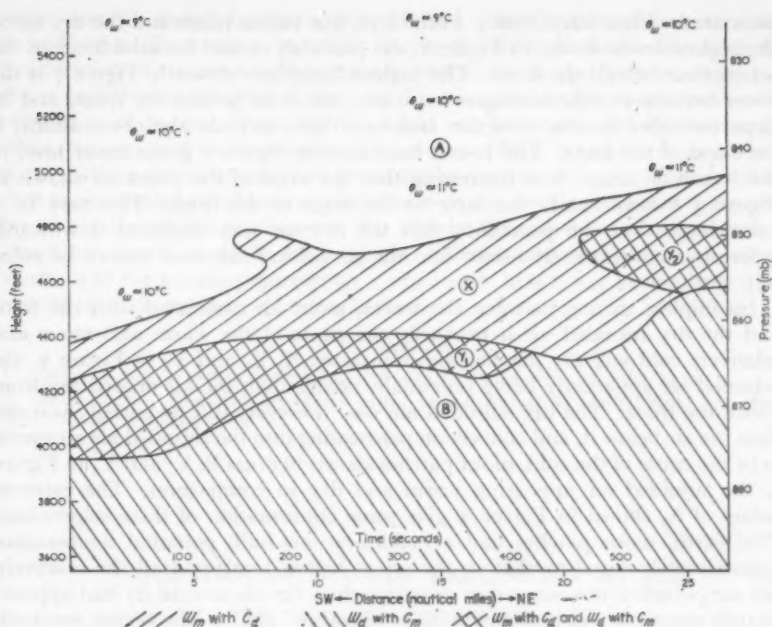
FIGURE 7—VERTICAL CROSS-SECTION SHOWING THE RELATIONSHIP BETWEEN
TEMPERATURE AND HUMIDITY OF PATCHES AS INDICATED BY THE CONTINUOUS
RECORDS

W_m Warm and moist patches, $\theta_w = 10\cdot5°C$.
W_d Warm and dry patches, $\theta_w = 6\cdot0°C$.
C_m Cold and moist patches, $\theta_w = 9\cdot5°C$.
C_d Cold and dry patches, $\theta_w = 6\cdot0°C$.

This diagram shows four quite distinct régimes in five areas. In the top area
(A) the air was relatively free of temperature and humidity fluctuations. In
the bottom region (B) temperature and humidity fluctuations were frequent,
the moist air being colder than the dry. Between these two regions there was
a sloping zone which included an area (X) in which the moist air was warmer
than the dry and two smaller areas (Y_1 and Y_2) in which the moist air was
sometimes warmer and sometimes colder than the dry. The boundaries of the
zone were sloping at an angle similar to that found in the temperature and
dew-point cross-sections.

No mention has yet been made of the vertical velocity measurements. In
clear air at all levels above 4000 ft the vertical velocities were nearly always
less than 3 ft/s which was about the limit of accuracy of the measurements. It
was not, therefore, possible to obtain much information about the motion of
the patches. Within clouds, however, vertical velocities were greater and
values of up to 6 ft/s were obtained. Below cloud level (as seen in Figure 6)
there were updraughts and downdraughts of up to 8 ft/s.

Discussion.—The observations appear to have been made at a time when
dry air associated with a subsidence inversion was being replaced by moist air

39

associated with a warm front. Frontolysis was taking place and the dry air at the highest levels shown in Figure 1 was probably caused by subsidence in the warmer air behind the front. The highest boundary shown in Figure 7 is the lower boundary of the homogeneous warm, moist air behind the front, and its slope (modified by the advection and time taken to make the observations) is the slope of the front. The lowest boundary in Figure 7 is the lower level of the transition zone. It is interesting that the slope of the driest air shown in Figure 3 is very nearly the same as the slope of the front. This may be a coincidence, but the possibility that the dry air was displaced downwards before it was completely mixed into the air behind the front cannot be ruled out.

Incomplete mixing between the warm, moist air associated with the front and the dry subsided air is probably the cause of the warm and moist and relatively cold and dry patches shown in areas X, Y_1 and Y_2 in Figure 7, the subsided air apparently being potentially colder than the air originating from above the front. The dry subsided air was, however, still potentially warmer than the air below it, and convection penetrating into the subsided air appeared to be the cause of the cold, moist patches shown in areas B, Y_1 and Y_2 in Figure 7, the subsided air appearing warm and dry in comparison. The extreme values of θ_w shown in Figure 7 give some confirmation of these suggestions. The warm, moist patches had a maximum wet-bulb potential temperature approximately equal to that in the air at higher levels and all the relatively dry air (whether it was warmer or colder than the air around it) had approximately the same wet-bulb potential temperature (6°C). The higher wet-bulb potential temperature at low levels compared with the dry subsided air, despite the probability that the air mass was the same, was probably due to its modification at low levels by radiative processes.

The fact that patches of air within the transition zone can still have their sources identified by their wet-bulb potential temperature shows that the mixing is very incomplete. It appears that the air motion is confined to a relatively large scale and that mixing on a small scale is very slow. The sharp boundaries between the air of different sources shown in Figures 4 and 5 confirm this.

The fact that the vertical velocities of the warm patches were small requires some explanation. A warm patch with an excess temperature of 1 degC should accelerate upwards at a rate of 1/9 ft/s², i.e. after one minute, neglecting drag, it should have a vertical velocity of about 6 ft/s relative to the colder air around it. The fact that no velocities greater than 3 ft/s were found means that any one patch could not have maintained its temperature differential relative to its surroundings for more than about half a minute. In that time it could not have risen more than about 50 ft. By rising this distance it must have found itself surrounded by air warmer than itself and started to decelerate. It appears that the density structure must have been such that, under the influence of buoyancy forces alone, the patches could only move upwards and downwards with small velocities over small distances.

Another observation on this flight worth discussion is the difference in temperature between the cumulus clouds and their surroundings and the depth of penetration of the clouds in which cloud temperature was estimated to be about 2½ degC colder than the air around it. Similar estimates on all the clouds traversed showed that the mean excess temperature of the environ-

ment over the clouds increased from about 1·3 degC at cloud base to about 3 degC near cloud top at a height of 500 ft above the base. The resulting deceleration of the air would bring it to rest at about 370 ft above cloud base if the initial velocity were 8 ft/s. As the air entering the cloud base had a vertical velocity of less than 8 ft/s it could not have ascended to cloud top if these temperature measurements are correct. If it is assumed that air is entrained the deceleration of the air would be even more rapid. It seems likely that the estimated cloud temperatures were on the low side and that there must be no significant mixing between the cloudy air and the air around it as a cloud penetrates a stable environment. This is another indication of the slowness of the mixing processes on a small scale in a stable atmosphere when mixing on a larger scale is known to exist.

REFERENCES

1. GRANT, D. R. ; Waves in an inversion layer. *Met. Mag., London,* **94,** 1965, p. 34.
2. GRANT, D. R. ; The Hastings aircraft of the Meteorological Research Flight. *Met. Mag., London,* **93,** 1964, p. 47.

VARIATION OF SHOWER FREQUENCY AT SEA

By W. D. SUMMERSBY, B.Sc.

Summary.—About 65,000 observations made at hourly intervals at OWS I and J were analysed to show the variation in the frequency of shower-hours with month, wind direction and the time of day. Tables are presented to show the probability that a shower-hour may occur in a given month and with a given wind direction. Most shower-hours occurred when the wind was from between west and north-west and fewest occurred when it blew from between south and south-east. The diurnal variation was slight and no consistent maximum was found at OWS I or J in the early morning.

Introduction.—At the end of June 1965 a 4-year period was completed during which the ships at ocean weather stations I and J had attempted to make observations at hourly intervals. In spite of all the difficulties, including duties that took the ships off station, hourly observations were made for the two stations on about 93 per cent of possible occasions. These observations have been transferred to Hollerith cards, making the selection of specific elements and the totalling of their frequencies comparatively easy. Over 65,000 cards, divided about equally between stations I and J, were dealt with in the analysis.

Briggs and Johns[1] (for Acklington) and Sims[2] (for St Eval and St Mawgan) have made similar analyses of data over 10-year periods. Their discussions make reference to the influence of the sea, distinguishing between the frequencies of showers in airflows arriving from the sea and those from the land. The impression given by sailors is that a maximum frequency of showers occurs fairly early in the morning, though whether this maximum is to be found throughout the year or whether its daily time varies during the year, is not known. An attempt was therefore made to determine the shower distribution at stations I and J in order to help in understanding events in coastal regions, quite apart from its own interest.

Annual variation.—The 65,000 cards were first sorted according to month and wind direction in 30-degree sectors, centred around 360°, 030°, etc., irrespective of wind speed. The resulting tabulations listed the total number of observations made at each station during each of the 48 months considered. The cards for each station then lay in 624 groups, including calms and light variable winds (5 kt or less) as a separate group in each month. From each of these groups those cards with present weather reported in international meteorological code[3] as 25, 26, 27 and 80 to 99 inclusive were selected and their totals listed.

The cards thus selected each represent an hour during which one or more showers occurred. Such hours will here be called shower-hours. It should be noted that shower-hours include frontal thunderstorms as well as thundery showers but the error accepted in the number of shower-hours by not excluding frontal thunderstorms is small. Small errors also result from using the wind direction recorded at the hourly observation since this might have been different when the shower occurred during the past hour. Gradient wind directions would have been preferable but were not readily available. The number of shower-hours does not correspond exactly to the number of showers. A shower lasting into the hour following the reported time of an observation will account for two shower-hours since it will be recorded as a shower in the past hour in the observation at the next hour. Offsetting this, to some degree, are those shower-hours during which several showers occurred prior to the observation, for which only one shower-hour is recorded. There may be a difference between the number of showers reported in day-time as compared to night-time, e.g. at night rain mixed with spray during a storm may not be reported as rain but be mistaken for spray because of its salty taste. All these errors may affect the absolute values of the frequencies found, but make little difference to the comparisons to be discussed.

Figure 1 shows the annual variation, on a monthly basis for both stations, of the frequency of shower-hours expressed as a percentage of the number of hourly observations made in the month. For both I and J there is a clear minimum in July. The maximum clearly occurs in January at OWS J, but at OWS I there is a broader maximum from October to January with its peak in November. In every month except January there is a larger proportion of shower-hours at OWS I than there is at OWS J. In January the proportions at the two stations are nearly equal. In all, about 16 per cent of observations at OWS I were shower-hours, but there were only about 13 per cent at OWS J, possibly reflecting the frequencies with which deep cold air overlies these stations. On a monthly basis however, the biggest difference between OWS I and OWS J occurred in April, and the least occurred in January, the only month in which there were more shower-hours at OWS J than OWS I.

Table I shows the differences between OWS I and OWS J in the numbers of shower-hours occurring during the four years, in months and seasons.

TABLE I—DIFFERENCES (OWS I MINUS J*) IN NUMBER OF SHOWER-HOURS

December	90	March	160	June	39	September	63
January	-2	April	262	July	41	October	151
February	21	May	42	August	38	November	105
Winter	109	Spring	464	Summer	118	Autumn	319

*Number of showers at J adjusted by the ratio of the numbers of observations made at I and J.
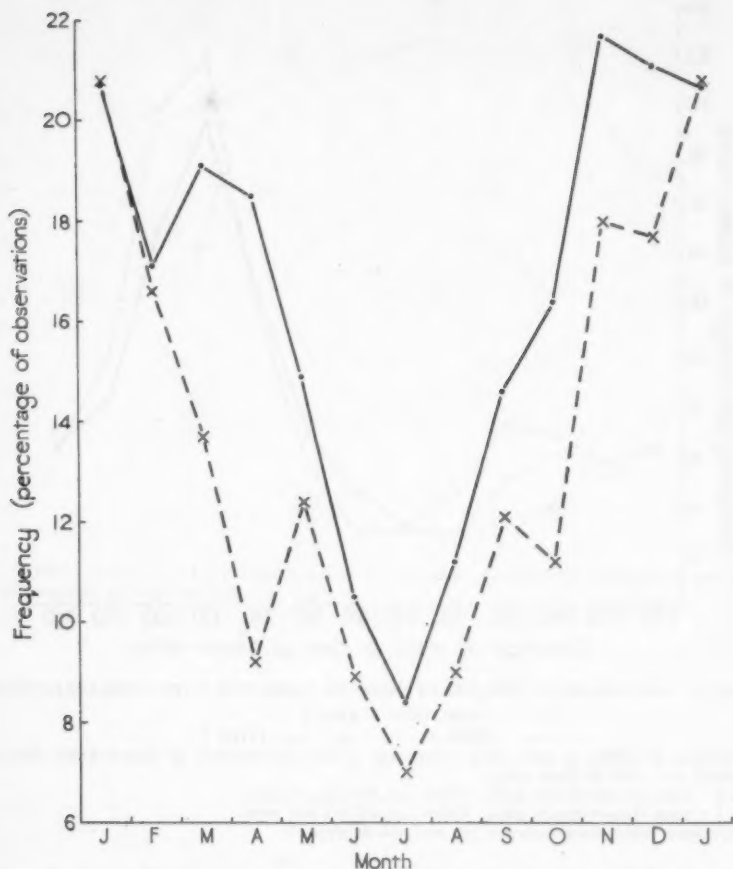
FIGURE 1—SHOWER-HOUR FREQUENCY EACH MONTH SHOWING VARIATION DURING
THE YEAR FOR OWS I AND J
•——————• OWS I   x— - —x OWS J
Shower-hour frequency is given as a percentage of the number of hourly observations made
for each of the 12 months during the period July 1961 to June 1965.

Distribution of shower-hours with wind direction.—Figure 2 shows,
for OWS I and J, the frequency of shower-hours for 12 wind directions,
irrespective of the time of the year. The shower-hour frequency is expressed as
a percentage of the total number of shower-hours during July 1961–June 1965.
Both ocean weather stations have a clear maximum at about 280° and a minor
one at about 070°. The minimum at about 150° may be explained by the low
probability of showers with winds from 150° (Figure 3(b)) and the minimum
at about 030° may be attributable to the low probability of winds from 030°
(Figure 3(a)).

Figures 3(a) and (b) show the wind distribution for OWS I and J along with
the shower-hour frequency as a percentage of the number of observations
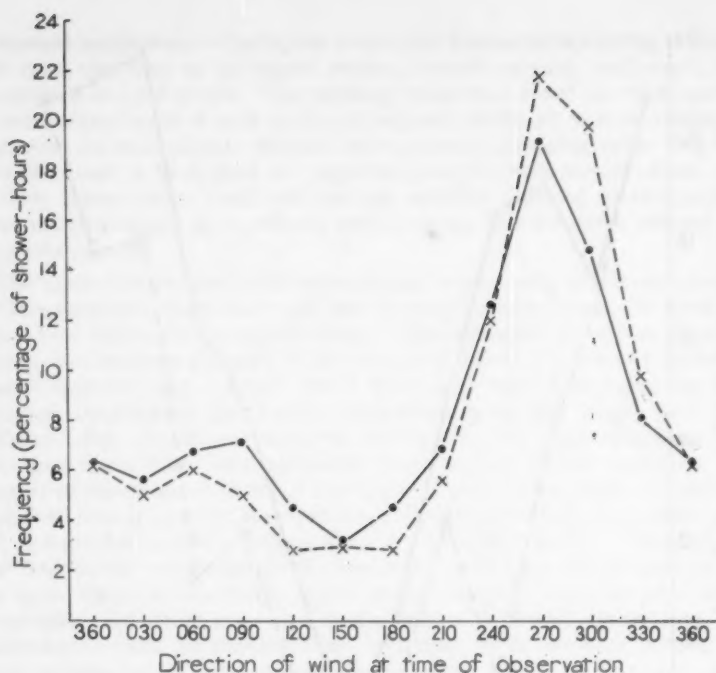for the specified wind direction throughout the period.

FIGURE 2—SHOWER-HOUR FREQUENCY SHOWING VARIATION WITH WIND DIRECTIONS
FOR OWS I AND J

•——————• OWS I   x— – –x   OWS J

Shower-hour frequency is given as a percentage of the total number of shower-hours during
the period July 1961 to June 1965.
OWS I : total shower-hours, 5387. Calm (<5 kt) 0·5 per cent.
OWS J : total shower-hours, 4204. Calm (<5 kt) 0·1 per cent.
360 represents winds from between 350 and 010 degrees.

Probability of shower-hours.—Table II(*a*) lists, for a given month and
wind direction, the average value for the 4 years of the ratio of the number of
shower-hours to the total number of observations with the same month and
wind direction. The ratios are expressed as percentages and represent
consistently the probability that any hour will be a shower-hour, given that
it is during a certain month and that the wind is from a specified direction.
The probabilities for OWS I and J are listed separately. Table II(*b*) gives for
each direction the wind frequencies as percentages of the total number of
observations.

It may be seen that both stations have a broad sector between about 110°
and 220° in which showers do not occur so often as they do in winds from other
directions, while most shower-hours occur in winds between 260° and 310°.
Further, shower-hours are least likely in the summer months.

Diurnal variation.—The shower-hour totals and numbers of observations
were machine-counted at each hour of the day, so that average values of the
ratio of the two could be computed and expressed in percentage form. Table
III shows, for three-hour intervals, the sum of the hourly values occurring

44
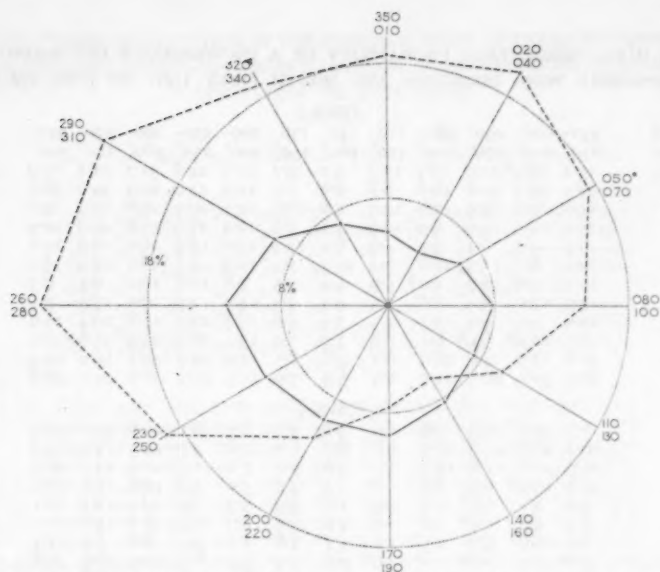
(a)   OWS I. Calm (≤5 kt) : wind polygon 1·4 per cent, shower-hour polygon 5·2 per cent.
Total number of observations : 33,254.
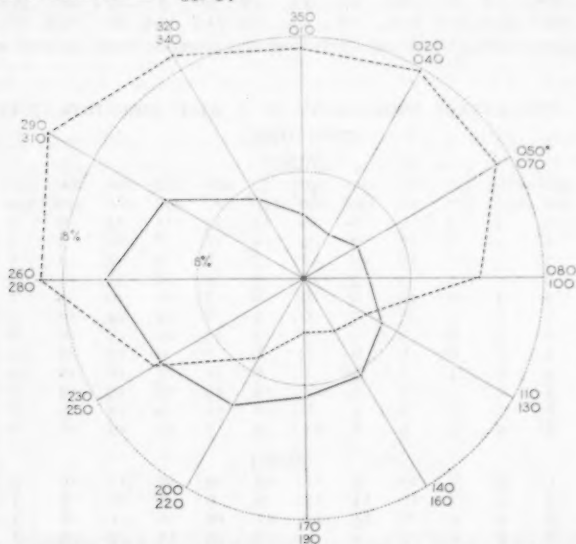
(b)   OWS J. Calm (≤5 kt) : wind polygon 1·0 per cent, shower-hour polygon 1·9 per cent.
Total number of observations : 31,738.

FIGURE 3—WIND POLYGONS AND SHOWER-HOUR FREQUENCY POLYGONS EXPRESSED
        AS A PERCENTAGE OF OBSERVATIONS FOR EACH WIND DIRECTION
———————   Percentage frequency of wind directions.
– – –   Shower-hour frequency expressed as a percentage of observations for each wind
            direction.
Based on data for period July 1961 to June 1965.

45

OWS I

Month	350–010°	020–040°	050–070°	080–100°	110–130°	140–160°	170–190°	200–220°	230–250°	260–280°	290–310°	320–340°	Calm or L/V
Jan.	15·2	25·3*	21·9	16·7	15·0	5·2	9·1	11·5	24·8	31·7	31·7	17·9	6·3*
Feb.	26·1	29·7	30·6	18·6	8·8	8·6	7·5	10·5	14·0	29·3	39·7	26·2	8·3*
Mar.	24·6	10·0	23·9	23·6	14·5	4·6	10·1	21·7	29·7	25·6	25·3	19·1	11·9
Apr.	22·0	18·1	13·3	8·9	10·9	3·3	8·8	12·2	23·9	35·8	29·8	22·3	3·3*
May	16·9	10·5	6·4	9·9	4·9	8·9	11·3	15·0	13·3	26·2	18·9	12·1	1·1*
June	12·9	6·7	11·3	10·8	9·4	20·3	7·4	12·5	14·1	16·2	12·3	13·1	1·5
July	12·1	4·6	2·7	1·0*	5·0	5·2	4·5	7·8	11·8	12·2	6·4	9·5	0
Aug.	13·9	17·0	8·4	8·8	5·3	4·3	4·4	14·3	14·9	16·3	17·9	9·1	11·7
Sept.	22·0	5·1	4·3	13·1	4·5	7·9	9·0	16·7	22·1	17·6	20·4	13·9	0
Oct.	18·7	10·2*	5·5*	8·1	8·3	7·7	7·9	15·1	20·9	25·9	33·8	22·1	3·6
Nov.	30·6	17·9	14·6	16·7	8·1	4·6	6·5	13·9	19·9	30·1	30·0	27·4	6·7
Dec.	28·1	30·1	22·7	11·3	8·3	5·9	7·0	11·3	21·1	28·7	25·2	28·8	18·8

OWS J

Month	350–010°	020–040°	050–070°	080–100°	110–130°	140–160°	170–190°	200–220°	230–250°	260–280°	290–310°	320–340°	Calm or L/V
Jan.	6·7	33·0	16·3	11·9	7·1	4·8	3·7	8·5	18·2	26·6	40·1	22·3	0*
Feb.	16·0	26·8	41·8	16·5	9·8	8·7	8·3	12·8	4·3	19·3	14·9	24·3	5·0*
Mar.	20·9	21·2	11·8	15·4	2·0	4·6	9·0	7·2	12·3	20·4	23·5	26·7	6·3
Apr.	40·2	10·9*	5·3	8·9	0	1·5	4·9	5·0	5·4	13·8	12·5	16·0	0
May	9·2	4·1	2·3*	2·9	2·9	1·6	5·9	5·3	17·9	23·5	17·1	18·1	1·1
June	8·5	4·7	1·9*	1·6	0	4·0	5·5	8·7	10·4	16·7	14·8	11·7	0
July	8·0	16·8	4·5	0·5	4·7	3·1	4·6	5·4	9·5	8·8	7·9	12·4	0
Aug.	5·8*	9·4	0·7*	0*	0*	2·8	2·4	3·5	8·1	10·9	18·3	8·8	0
Sept.	10·5	4·5	0	5·3	0	2·3	1·5	6·1	13·8	24·3	18·8	18·3	0
Oct.	16·1	13·3	0*	0	0*	2·7	1·1	4·4	15·5	23·3	20·1	14·6	3·1*
Nov.	28·0	2·8	6·7	8·2	6·9	4·9	0·8	3·1	9·7	25·4	28·2	35·8	0
Dec.	25·6	34·2	27·2	24·9	9·6	2·5	3·4	11·7	19·9	27·1	27·8	16·7	8·3

*Includes a month during which no winds from this direction were reported at an hourly
observation.

OWS I

Month	350–010°	020–040°	050–070°	080–100°	110–130°	140–160°	170–190°	200–220°	230–250°	260–280°	290–310°	320–340°	Calm or L/V
Jan.	5	3	5	7	7	10	13	13	11	13	9	4	0*
Feb.	4	4	7	13	13	9	14	11	8	10	4	3	0*
Mar.	5	7	10	16	14	12	7	6	7	4	4	7	1
Apr.	2	4	9	9	7	10	9	9	8	15	11	6	1
May	4	4	10	10	9	9	8	7	11	10	9	7	2
June	6	5	5	7	7	6	7	8	12	14	10	9	4
July	6	5	6	5	3	5	7	13	12	17	12	8	1
Aug.	9	7	6	6	6	6	8	7	9	10	12	11	3
Sept.	4	4	4	7	5	7	9	12	12	16	10	9	1
Oct.	5	2	1	2	5	7	14	14	18	13	12	6	1
Nov.	8	8	6	3	4	6	11	11	9	12	13	8	1
Dec.	8	4	5	9	6	11	9	7	11	12	11	6	1

OWS J

Month	350–010°	020–040°	050–070°	080–100°	110–130°	140–160°	170–190°	200–220°	230–250°	260–280°	290–310°	320–340°	Calm or L/V
Jan.	1	3	9	10	9	11	13	10	10	11	10	3	0*
Feb.	3	5	7	11	14	13	9	9	7	10	8	4	0*
Mar.	5	4	4	6	14	13	11	10	10	11	6	5	1
Apr.	6	3	4	3	4	9	7	10	14	19	13	7	1
May	3	3	5	5	6	7	8	10	15	17	12	7	2
June	4	5	5	3	4	7	9	15	15	16	11	4	2
July	10	7	4	4	4	2	5	10	16	17	11	9	1
Aug.	6	2	2	2	3	6	8	9	11	19	20	11	1
Sept.	4	4	2	2	3	5	8	17	15	16	15	8	1
Oct.	4	2	2	1	3	9	12	18	14	12	14	8	1
Nov.	8	3	3	4	7	8	6	10	9	12	15	14	1
Dec.	5	5	9	9	7	9	12	7	10	15	8	4	0*

o* denotes <0·5

TABLE III—THREE-HOUR TOTALS OF THE MONTHLY MEANS OF THE RATIO (EXPRESSED AS A PERCENTAGE) OF SHOWER-HOURS TO NUMBER OF OBSERVATIONS AT EACH HOUR (JULY 1961 TO JUNE 1965)

OWS I

Period of day* GMT	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.†	Oct.†	Nov.	Dec.	Mean per month
23–02	57·1	47·6	45·3	46·8	38·0	37·6	24·9	31·6	44·8	43·9	64·2	44·0	43·8
02–05	42·1	54·1	65·7	51·8	42·3	30·6	25·0	28·3	46·0	52·3	63·5	56·0	46·5
05–08	56·8	51·0	71·0	45·8	50·8	41·8	22·7	35·5	43·7	48·7	65·5	56·2	49·1
08–11	72·7	51·5	59·3	79·7	48·1	30·6	15·5	41·1	34·4	48·9	61·9	66·5	50·9
11–14	80·2	64·8	55·1	50·8	43·4	32·0	28·2	35·5	49·5	48·2	68·0	74·8	52·5
14–17	72·3	51·2	58·0	59·4	32·5	30·6	28·8	30·3	48·0	50·7	60·4	73·8	49·7
17–20	53·5	45·9	55·8	60·4	36·7	19·8	31·2	37·8	48·3	59·1	62·9	69·0	48·4
20–23	62·9	43·2	48·1	49·6	42·2	28·4	24·5	29·6	35·3	41·1	74·0	65·5	45·4

OWS J

Period of day* GMT	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.†	Sept.	Oct.	Nov.†	Dec.†	Mean per month
23–02	56·8	44·7	39·2	17·2	38·6	20·4	22·6	35·8	35·3	21·5	53·7	52·5	36·5
02–05	47·5	48·1	34·4	24·6	40·0	23·4	16·5	33·9	33·9	28·3	45·5	44·8	35·1
05–08	55·6	47·5	49·3	25·5	52·1	28·5	28·2	30·8	38·7	40·6	54·1	41·0	41·0
08–11	69·1	44·9	61·1	44·8	46·2	32·1	20·4	22·6	36·7	39·7	52·0	58·5	44·0
11–14	69·3	53·9	38·3	27·9	36·5	22·5	16·3	26·4	33·2	36·3	63·8	71·8	41·3
14–17	75·8	47·8	27·3	23·1	29·3	31·0	15·2	31·1	36·1	34·5	55·7	55·0	38·5
17–20	70·9	50·7	45·8	28·6	26·8	30·1	16·9	22·0	36·8	37·5	44·6	48·4	38·3
20–23	54·6	60·6	33·3	28·9	28·0	25·9	31·3	35·8	38·9	29·4	62·7	52·9	40·2

*Based on sets of three observations, i.e. 23–02 is based on observations at 0000, 0100 and 0200 GMT.

†In these columns insufficient observations were made in 1961 at non-synoptic hours and the means for non-synoptic hours were therefore calculated from the last 3 years. If 20 observations be regarded as sufficient to give a valid monthly mean, and all the missing observations happen to be shower-hours, the error for that month would be about 33 per cent and that for the figures in these columns about 16–20 per cent. That this should happen is most unlikely : most months were nearly complete at all hours, though a few had only 22 observations and were accepted.

within each three-hour period, OWS I and OWS J being listed separately. Figure 4 plots the last column of Table III against the period of the day.
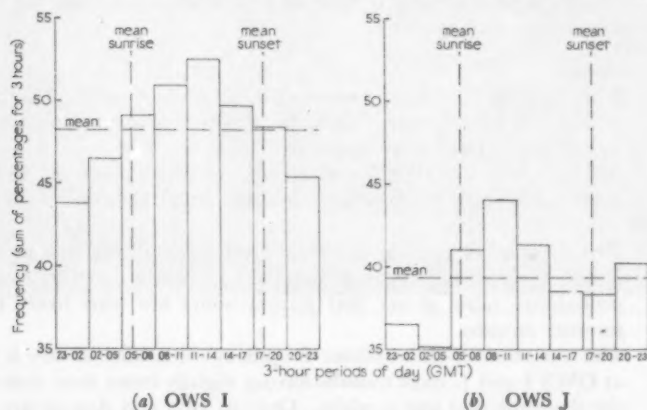

(a) OWS I   (b) OWS J

FIGURE 4—MEAN MONTHLY VALUE OF SHOWER-HOUR FREQUENCY FOR EACH SET OF THREE OBSERVATIONS DURING THE DAY

Frequency is expressed as the sum of the three percentages obtained for three-hour periods, e.g. for the period 2300 to 0200 the observations used were 0000, 0100 and 0200 GMT. Based on data for period July 1961 to June 1965.

The diurnal pattern of shower-hour frequency that occurs at OWS I is similar to, though less marked than that found over land, a maximum occurring at about noon or just before and a minimum at about midnight. However at OWS J the pattern is changed, the maximum being earlier at about 1000 GMT, and the minimum being one to two hours before dawn : there is in addition a subsidiary maximum shortly before midnight. It is doubtful if such small features at OWS J are significant. The pattern at OWS I is surprising in view of the negligible changes in sea temperature that result from a single day's insolation.

Since the values of Table III are for three-hour intervals, the hourly mean values are about one third of those shown and lie between about 10 per cent and 20 per cent. The excess of shower-hours by day is thus small. In no month did the time of both maximum and minimum hourly percentage agree at the two stations, though in April the maximum occurred between 1000 and 1100 GMT at both stations. The times of occurrence of both maximum and minimum were extremely variable from month to month for each station separately.

The daily analysis to this point was independent of wind direction, but it was found that when individual hours were considered the shower-hour frequency variation was similar to that given in Figure 2 when considering individual hours, and is therefore not shown.

An attempt was made to assess how far day-time shower-hours exceed those at night, taking the changing length of daylight through the year at the two stations into account. The results are shown in Figure 5. For both OWS I and J there is a slight excess of shower-hours by day in most months, and a slight deficit by night. Only in July and August is this distribution reversed and even then the excess by night is small. The smallest day-time deviations from the monthly average occurred in June and October, while the largest deviations were in December and January. At night the smallest deviations from monthly average occurred in June and October again, but the largest ones were in January and April.

Conclusions.—
  (i)   There is a fairly regular annual distribution of showers affecting the ocean weather stations I and J, in which a maximum occurs in winter and a minimum in summer.
 (ii)   Most showers at OWS I and J occur in winds from the west and north-west and fewest occur in winds from the south and south-east.
(iii)   The probability of a shower for a given wind direction and month is also greatest for westerly and least for south-easterly winds. A probability table shows that shower-hours are least likely in the summer months.
 (iv)   The variation of shower-hour frequency with time of day is slight at OWS I and J, most months having slightly more than average in the day-time and less at night. Only in July and August are there more shower-hours at night than by day, and even then the excess is small.
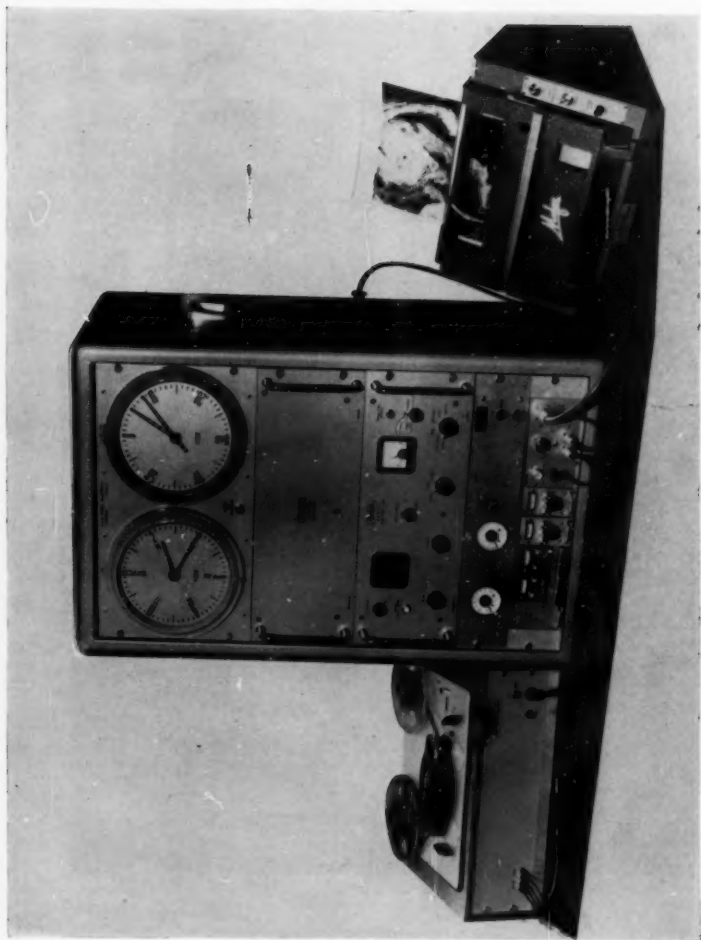 (v)   There is no consistent early-morning maximum in the diurnal distribution of shower-hours at OWS I and J.

Photograph by courtesy of Hawker Siddeley Dynamics Ltd, Coventry

PLATE I—THE APT RECEIVING STATION SHOWING THE PREFABRICATED HUT AND
AERIAL

PLATE II—APT RECEIVING EQUIPMENT INSIDE THE PREFABRICATED HUT

The central console contains the receivers and equipment controlling the aerial. The facsimile recorder is on the right and the tape recorder on the left. See page 58.

Crown copyright

PLATE III—MAJOR K. J. GROVES (LEFT), WITH MRS GROVES AND AIR MARSHAL
SIR REGINALD EMSON, PRESENTING THE MEMORIAL PRIZE FOR METEOROLOGY TO
DR N. E. RIDER

See page 62.

PLATE IV—MAJOR K. J. GROVES PRESENTING THE METEOROLOGICAL OBSERVER'S

AWARD TO MR B. W. BUTLER
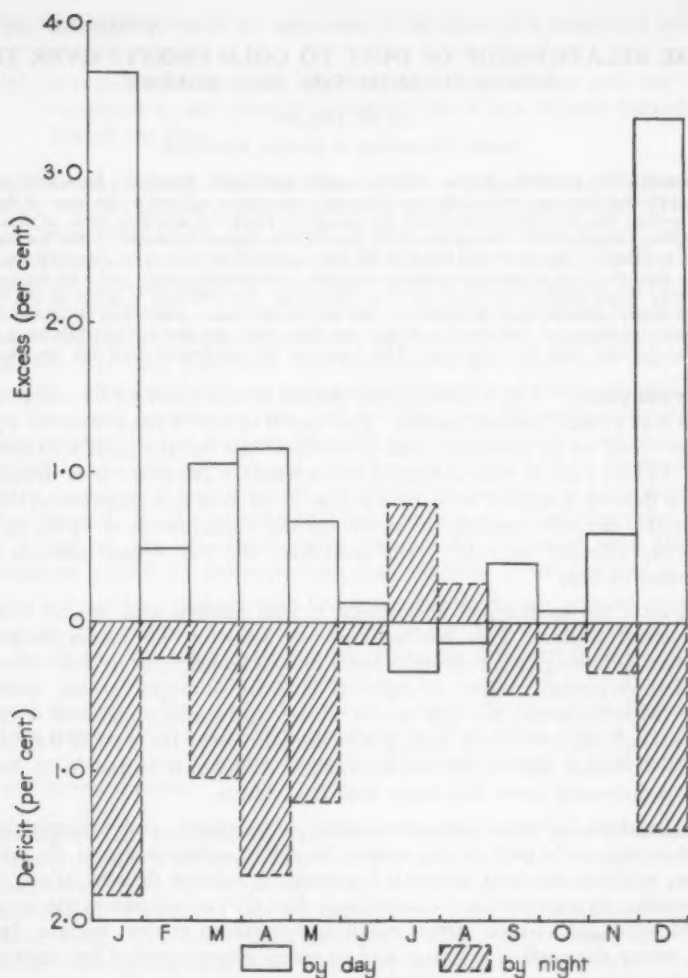
FIGURE 5—DIFFERENCES BETWEEN DAYLIGHT AND DARKNESS VALUES EACH MONTH
OF THE SHOWER-HOUR FREQUENCY

Shower-hour frequency is expressed as an excess or deficit compared with the hourly mean percentage for the month. OWS I and J data are combined for the period July 1961 to June 1965. Average monthly times of sunrise and sunset were used to define the hours of darkness and daylight.

REFERENCES

1. BRIGGS, J. and JOHNS, J. ; Variation in shower activity at Acklington. *Met. Mag., London*, **89**, 1960, p. 48.
2. SIMS, F. P. ; The annual and diurnal variation of shower frequency at St. Eval and St. Mawgan. *Met. Mag., London*, **89**, 1960, p. 293.
3. Geneva, World Meteorological Organization. Weather Reports, Vol. B. Geneva, WMO, 1964.

THE RELATIONSHIP OF DUST TO COLD FRONTS OVER THE SUDAN DURING THE DRY SEASON

By M. DELSI*

Sudan Meteorological Service, Khartoum

Summary.—The traditional theory relating dust to cold fronts during the dry season (winter) over north and northern central Sudan limits the occurrence of dust to the rear of the front and therefore has the effect that fronts are placed to mark the southern limit of dust. This theory works satisfactorily during the early part of the season. However, if the leading edge of dust is taken to represent the front in the later part of the season — generally April and May — then the front appears to progress unevenly with sudden jumps and with temperature apparently rising behind the front on some occasions. An example is given of the type of analysis under consideration. It is shown that late in the season a dust belt 60 to 200 n.miles wide develops ahead of cold fronts and that the edge of the pre-frontal dust belt need not be taken as the real cold front position. The causes of the pre-frontal dust belt are discussed.

Introduction.—The weather of the Sudan is characterized by a dry winter season and a rainy summer season. The length of any of the seasons at a place is determined by its position north or south of the Intertropical Convergence Zone (ITCZ) and is thus a function of latitude. Therefore it is difficult to assign a definite length of time for a season in an area covering several degrees of latitude. Broadly speaking however, for the Sudan north of 13°N, an area frequently affected by cold fronts and dust, the dry season extends from November to May.

In winter the subtropical anticyclone is well marked and usually situated over central Sudan. This anticyclonic cell however, undergoes noticeable oscillation following major developments in middle latitudes over Europe and the Mediterranean. When a vigorous cold-air outbreak occurs over the eastern Mediterranean the cell moves to the south and sometimes it breaks into two, one cell over south Arabia and the other over the west of the Sudan. This development allows the Mediterranean cold fronts to reach the Sudan and in pronounced cases they move into East Africa.

The freedom of the winter atmosphere from clouds and precipitation is caused in the early part of the season by active subsidence and by relative dryness, while in the later season it is caused by relative dryness alone. The only weather experienced is the occasional dust that accompanies the invasion by cold fronts and which affects north and northern central Sudan. In the south, where the surface is firmer and in many places covered by vegetation, suspended dust is sometimes carried into the area.

Widespread dust in winter has traditionally been taken to be associated with a cold front and to occur behind it in the area of strong winds caused by a steep pressure gradient developed by rising pressure behind the front. This has become a fundamental theory of analysis for the Sudan and therefore cold fronts are normally placed to mark the leading edge of the dust. The object of this paper is to examine the validity of this established theory and to find an explanation for the two paradoxical points that arise occasionally when the traditional analysis is made during the late season (generally April and May) :

---

*The writer is on a WMO OPEX assignment in the Sudan.

(*a*) A sudden jump in the movement of the front over north and northern central Sudan.

(*b*) A considerable time-lag between the frontal passage and any fall in temperature, and even an occasional rise of temperature immediately behind the front.

Traditional theory linking dust with cold fronts.—Sutton[1] was probably the first to relate dust to cold fronts. In a paper entitled 'Haboobs' he says 'Sometimes in the dry season (winter) cold air from Egypt, generally that of the cold sector of a depression which has traversed the Mediterranean, passes to the extreme south of the Sudan and causes sandstorms and haboobs in the northern Sudan.' Later Freeman[2] summed up previous knowledge as follows: 'During the winter, depressions move eastwards across the Mediterranean Sea and their associated cold fronts move south-east and south across the Sahara. Many of the winter duststorms are associated with these cold fronts. When the system is vigorous very cold air from Asia streams southwards, and as it moves over the hot sand considerable instability develops. An anticyclone builds up in the cold air giving a steep gradient behind the cold front. The resulting strong wind together with the instability combine to form large areas of blowing sand. By the time the cold front reaches the Anglo-Egyptian Sudan most if not all the associated cloud has usually dispersed, and the front continues as a wind discontinuity with poor visibility to the north of it.'

Over the northern Sahara cold fronts are easy to locate because of the vast differences in air mass characteristics. But as the cold air streams southwards into the Sudan it undergoes some modification although many cold fronts maintain clear characteristics demonstrated by wind discontinuity, dust and thermal gradient. The thermal gradient is at its maximum in January and weakens gradually but is still recognizable in May when it is at its weakest. Figure 1 shows an early season example of frontal passage in conformity with the traditional theory.

Examples of traditional analysis during the late season.—The application of the traditional theory to the analysis of late season fronts often produces a sudden jump in the movement of the front over north and northern central Sudan. Figure 2(*a*) gives successive positions of a cold front from 10 to 13 April 1965. This is a typical example of cold front invasion and is taken from the working charts at Khartoum forecast office. The method of analysis employed was that of traditional theory. The sudden jump in the progression of the front is readily observed between 11 and 12 April. The average speed over 24 hours was 20 knots ; but the 6-hourly positions show that the jump occurred during an 18-hour period giving an average speed of 27 knots and in certain sectors an even higher speed (42 knots) which is difficult to explain.

Figure 2(*b*), reproduced from Sutton,[1] shows a similar phenomenon during April 1929. The speed of the front in the north averaged 13 knots and between 20 and 21 April the front leapt a considerable distance with an average speed of 25 knots but no explanation was given for the sudden acceleration.

Example of analysis postulating a pre-frontal dust belt in the late season.—The charts of 11 and 12 April 1965 were analysed again (Figure 3(*a*) and (*b*)) employing temperature considerations and a steady progression of the
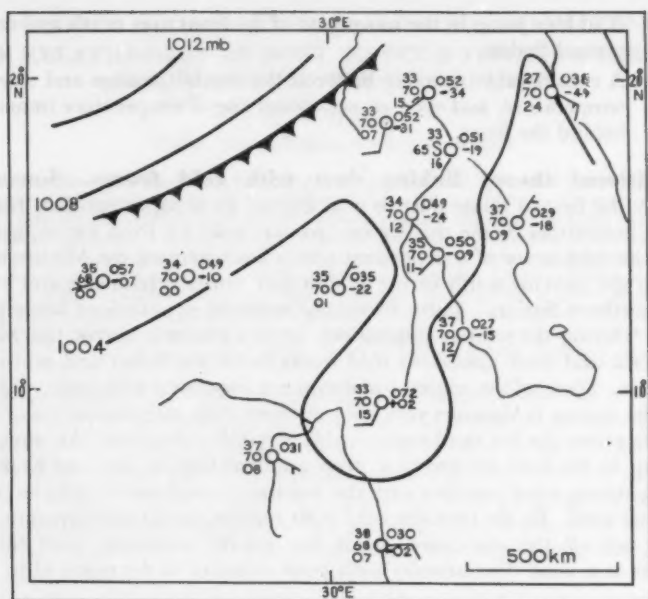
(a) 18 January 1965
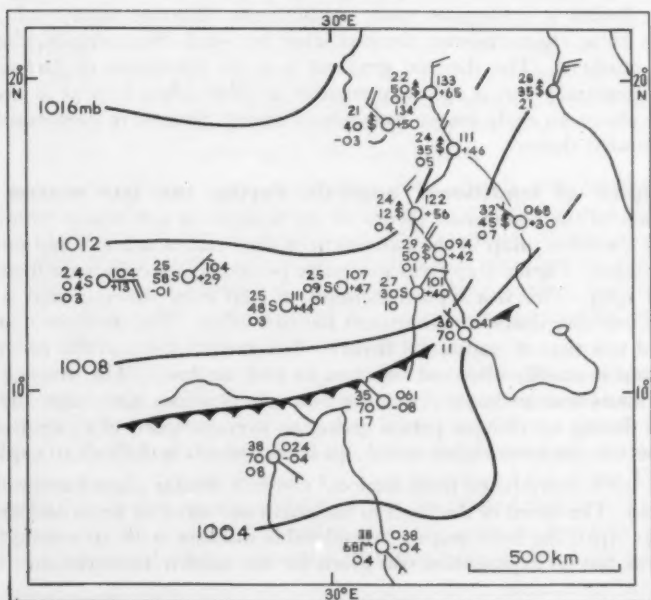
(b) 19 January 1965

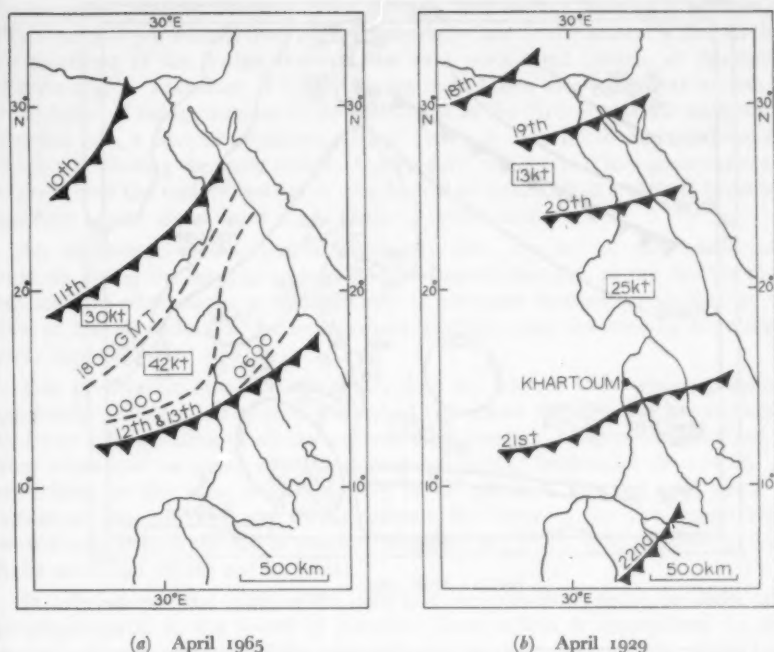FIGURE 1—EXAMPLE OF EARLY-SEASON FRONTAL PASSAGE AT 1200 GMT

(a) April 1965   (b) April 1929

FIGURE 2—POSITIONS OF COLD FRONTS AT 1200 GMT

front without rega   he dust, the 24-hour pressure tendency and the wind
discontinuity. U   .luence of a developing and mobile anticyclone the
northern portion of t.   nt between 10 and 11 April travelled faster than the
southern part and the orientation of the front changed to east-north-east to
west-south-west by the 11th thus slowing down the south-east motion. It will
be noted on Figure 3(a) that at 1200 GMT on the 11th the pressure gradient
just ahead of the front is nearly equal to that behind it and dust is reported
over south Egypt. During the following 24 hours (Figure 3(b)) the steep
pressure gradient ahead of the front built up in a wider belt within the warm
air over northern central Sudan to produce a pre-frontal dust belt about 180 n.
miles wide. On traditional theory the leading edge of this dust belt would
have been taken as the cold front which would thus appear to have progressed
forward in an irregular jump to its new position. There would also be a time-
lag between the 'frontal passage' and the fall of temperature, and a secondary
cold front would have to appear suddenly in the analysis over north Sudan to
mark the fall of temperature.

The causes of pre-frontal dust belts.—The production of dust is depend-
ent on instability and strong wind speed and there seems no valid reason for not
accepting that dust can be raised ahead of the front as well as behind it when

53

(a) 11 April 1965

(b) 12 April 1965

FIGURE 3—EXAMPLE OF PRE-FRONTAL DUST BELT AT 1200 GMT

ITCZ Intertropical convergence zone   – – – Dust edge

54

the pressure gradient becomes steep enough, and surface heating is sufficient. The fact that pre-frontal dust occurs frequently late in the season is due to the development of the Sudan thermal low as a permanent feature at this time (Figure 4(a)). Therefore, if high pressure over Libya moves eastwards with a component of rising pressure to the south-east in the direction of the stationary thermal low, a steeper pressure gradient develops over north Sudan ahead of the front. During the early season (Figure 4(b)) the thermal low is almost non-existent and the surface isobars lie nearly east to west so that a steeper pressure gradient ahead of the front is not likely to be established.

An important factor, which previously lent support to the traditional analysis giving the leading edge of the pre-frontal dust belt as the front is that the leading edge marks a discontinuity in pressure tendency very similar to that at a front although the temperature gradient near the leading edge does not suggest a front.

The pre-frontal dust belt, however, does not always show rising pressure tendencies within it. Towards the end of the season the thermal low expands to cover a larger area of about uniform temperature. Its pressure gradient is very weak and on many occasions there are falling tendencies all over it. A cold front at this time is usually very weak and slow moving, and when it advances into the low any rising pressure tendency in the pre-frontal area would only reduce the fall of pressure ahead of the front. Any pre-frontal dust belts produced would not be wide.

It is found that the width of the dust belt varies from 60 to 200 n. miles and is proportional to the speed of the cold front, which is determined by the magnitude and mobility of the anticyclone to its rear. The activity of the belt is obviously proportional to the pressure gradient developed within the belt.

The front and surface temperature.—Since a front is basically by definition a thermal discontinuity, the traditional theory relating dust to cold fronts implies that the temperature must drop at the passage of the front and the onset of blowing dust ; this is observed to occur during the early season but not during the later part of the season.

Solot[3] observed that the temperature does not react immediately to frontal passage (edge of pre-frontal dust belt) and stated that even in the most vigorous fronts the drop in temperature may occur as much as 12 to 18 hours after the frontal passage ; he did not specify the period of the season but undoubtedly his data apply to the latter part. Now if the real cold front is considered to be well to the north of a station which has just been affected by a pre-frontal dust belt there should be no material change of temperature for some hours, and even a rise of temperature would not be surprising since the air mass has not changed. Solot's figures suggest an average time-lag of 15 hours between the arrival of the dust edge and the real cold front. In this time the average fast moving front moving at 13 knots over northern central Sudan would cover a distance of 195 nautical miles which agrees with observations of the width of a pre-frontal dust belt.

There is no support for the suggestion advanced locally that subsidence can explain why temperature does not fall and may even rise behind the dust edge late in the season. Subsided air does not reach the ground in Sudan and if it did its effect should be more noticeable during the early season when subsidence
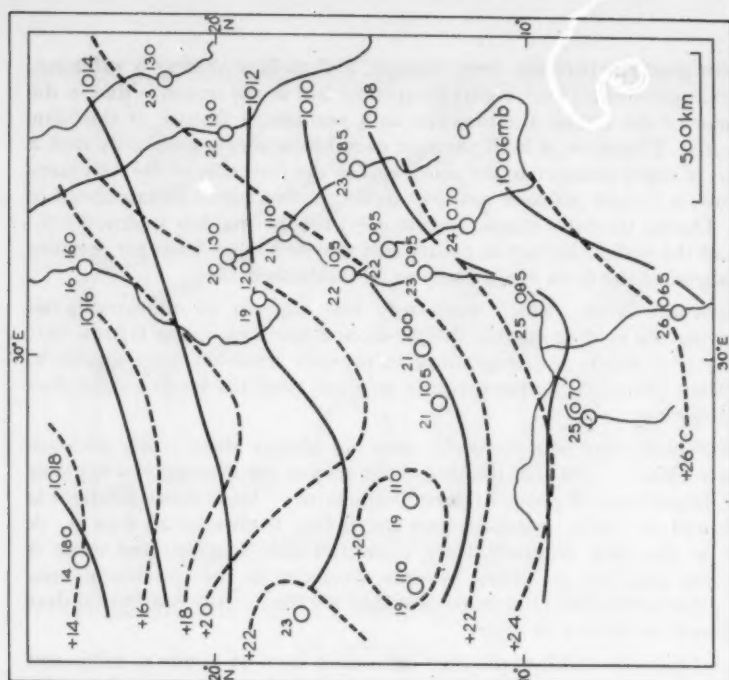
FIGURE 4—MEAN MSL PRESSURE AND SURFACE TEMPERATURE

—— Pressure – – – Temperature

(a) April 1965

(b) January 1965

is much more active. Temperature soundings at Khartoum during the late hot season show an adiabatic lapse rate up to a considerable height. Subsidence behind the dust edge would not cause a change in the surface temperature.

Analysis by temperature change.—Figure 5 gives the maximum temperatures recorded on successive days (11, 12 and 13 April) at various stations and also shows the positions of the cold front between 12 and 13 April 1965 as analysed employing the temperature considerations described in this paper. The most reliable method for locating the cold front is to use a steady progression of the front and to note the passage of the front by observing a drop in temperature compared with temperature 24 hours earlier at the same station.
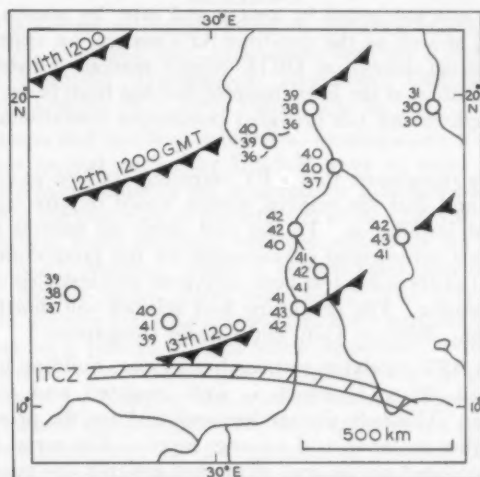
FIGURE 5—MAXIMUM TEMPERATURE AND POSITIONS OF FRONTS, APRIL 1965
ITCZ Intertropical convergence zone
Maximum temperature for 11 April denoted by top figure at station circle
Maximum temperature for 12 April denoted by middle figure at station circle
Maximum temperature for 13 April denoted by bottom figure at station circle

REFERENCES

1. SUTTON, L. J. ; Haboobs. *Q. Jnl R. met. Soc., London*, **57**, 1931, p. 155.
2. FREEMAN, M. H. ; Duststorms of the Anglo-Egyptian Sudan. *Met. Rep. London*, **2**, No. 11, 1952.
3. SOLOT, S. B. ; The meteorology of Central Africa. Weather Research Center, 19th Weather Region, Accra, 1943, p. 38.

AUTOMATIC PICTURE TRANSMISSION RECEIVING STATIONS FOR THE METEOROLOGICAL OFFICE

By N. E. RIDER, D.Sc.

NIMBUS I, the second satellite to carry experimental automatic picture transmission (APT), was launched in August 1964. Since then the Meteorological Office has maintained an APT receiving station at the Experimental Site some three miles from the Bracknell Headquarters. This station was made by the Instruments and Observations Branch from surplus equipment and commercially available receivers and, to date, has been the only means whereby 'readouts' have been obtained for use within the Meteorological Office including the Central Forecasting Office (CFO). NIMBUS I after a short operational life was succeeded by ESSA II and later by NIMBUS II. This latter satellite carried, as well as the day-time APT system, an experimental nighttime readout system, known as DRIR (direct readout infra-red). The hand-built prototype station at the Experimental Site has been in use throughout the life of these satellites and has provided continuous operational coverage over the past year.

It was always recognized that APT receiving stations would be needed at other locations and that the original station would require replacement by a more permanent installation. To this end, some six months ago, a contract was awarded to a commercial organization for the production of five equipments. The first of these has just been delivered and installed on the same site as the original station. The remaining four stations will shortly be erected at Episkopi (Cyprus), Bahrain, Gan, and Changi (Singapore).

Each of these APT receiving stations has its own building in the form of a prefabricated hut (Plate I) which is well insulated and contains an air-conditioning unit. The only site services required are the provision of a base of concrete or other material, and a power supply. The aerial is an eight-turn helix which is mounted on the roof of the hut towards one corner. Its weight is taken by a column which extends from the roof to the base. The aerial is capable of being directed over 180° of elevation and 720° of azimuth by electric motors which are controlled from the operating position within the hut, the elevation and azimuth bearings of the aerial being indicated on dials. The equipment console (Plate II) contains, in addition to the aerial control gear, duplicate preamplifiers and receivers. Both receivers may be used in either the crystal or manual tuning modes and are capable of receiving F.M. and A.M. signals. Either receiver may be connected, by means of a patch panel, to either preamplifier and either of the latter may similarly be connected to the aerial. There is thus a complete duplication of the receiving equipment so that loss of reception as a result of equipment failure should be very rare. The output from the receiver in use at any particular time may be fed to a facsimile machine provided as part of the station equipment and, via a voltage controlled oscillator, to one channel of a twin channel magnetic tape recorder. The tape recorder's second channel is used to record the fork frequency derived from the facsimile machine so that, on replay, the picture obtained can be held in synchronism. The magnetic tape recording taken during a satellite pass may be subsequently played back into the facsimile machine to produce additional copies of the readout. This tape recorder also guards against a

complete loss of picture in the unlikely event of breakdown or faulty operation of the facsimile machine during a particular satellite pass.

The first of these manufactured stations was planned to be fully operational early in January 1967 in time to receive the first readouts from the new ESSA satellite which is replacing ESSA II. The hut at the Experimental Site will have land-line facilities to pass picture readouts direct to the communications centre in the Headquarters building as they are received. In this way cloud pictures will be available in CFO only a matter of minutes after their reception. The original station will then become available for further development work, initially in connexion with the reception of DRIR readouts, a facility which might well be added to the five operational stations at a later date .

REVIEWS

The Hydrologic Cycle in the Atmosphere, by O. A. Drozdov and A. S. Grigor'eva. 7 in × 9½ in, pp. vi + 282, *illus.*, (translated from the Russian by the Israel Program for Scientific Translations, Jerusalem), Oldbourne Press, 1–5 Portpool Lane, London EC1, 1965. Price : £5. 8s.

The Preface states that this book is based on investigations of the hydrological cycle which were carried out in the U.S.S.R. over 15 years and upon other Soviet and non-Soviet studies of the atmospheric moisture balance. 'Most of the data quoted in the text refer to the territory of the U.S.S.R. or to individual parts of it. However, some problems were also solved for the middle latitudes of Eurasia and North America, while in certain cases data for the Northern Hemisphere or for the entire globe were used.' The Preface proceeds to indicate that the authors are geographers, and their first chapter contains the following passage as a pointer to their whole approach. Whilst the problem of 'the interaction between the atmospheric moisture and the precipitation and runoff . . . is solved by studying the relation between the evaporation from specific territories and the precipitation', there is 'a second problem, which is probably no less important, . . . the connection between the formation of precipitation in the atmosphere . . . and condensation nuclei and their circulation', but 'the latter problem will not be considered'.

A review of some of the authors' compatriots' past ideas is followed in Chapter II firstly by a set of mildly interesting though inadequately explained maps of 'Ratio between moisture content of atmosphere (mm) and absolute humidity at earth's surface (mm)'—a ratio that would seem, on close inspection, not to have been really non-dimensional—and secondly by a 'theory describing exchange between local and advective moisture', a theory that is physically and geographically idealized and loaded with algebra that is neither wholly useful nor wholly free from misprints.

After two further sections of Chapter II—'Calculations of atmospheric transfer' and 'The transport of water vapour and heat over Eurasia', the precision of whose tables and quantitative statements seems incommensurate with their informativeness—there comes a chapter bearing the stimulating title, 'The relation between the precipitation field and the atmospheric humidity'. In this, moreover, a sub-section that is even more enticingly entitled 'Application of the correlation of moisture content and relative humidity with precipitation to short periods' contains scatter-diagrams of 'moisture content in layer up to 500 mb surface and daily precipitation

59

averaged over the territory' of the southern European U.S.S.R. The scatter being very considerable, there seems less meat in all this than might have been hoped for. But the linking of the precipitable water of the layer up to the 500 mb level with the ensuing daily totals of rainfall is an obviously attractive idea that has enjoyed favour outside as well as inside the U.S.S.R. ; ideas which derive from it are embodied in current Meteorological Office research.

In a sub-section stemming quite naturally from the last one, entitled 'The moisture content of the atmosphere', are some Northern Hemisphere maps which constitute what is perhaps the high spot of the book. The writers acknowledge the Meteorological Office's well-known version given in *Geophysical Memoirs* No. 102, which, however, illustrates mid-season months only. In the book there is a separate map for each month of the year. The map projection, incidentally, differs from that of *G.M.* No. 102 in being polar and nearly equidistant : in synoptic work this is handy.

What has just been said about the precipitable water maps would imply there to be nothing much in the remaining (and physically bulkier) part of the book. Of the final five chapters, suffice it to say that their titles are 'Properties of the hydrologic cycle in mountainous regions', 'Moisture flux in the atmosphere', 'The coefficient of macroturbulent exchange', 'The hydrologic cycles for individual regions of the U.S.S.R.', and 'The effect of improvement measures on the hydrologic cycle', and that they seem to have more breadth than depth.

The reviewer has not been in a position to judge how well the original Russian text has come through ; but whilst acknowledging the English rendering to be free from jarring infelicities and generally pleasantly readable he cannot but feel the whole work to be far more wordy than informative. However the printing and layout are reasonably clear.

There are finally 247 listed references to publications that were originally in Russian, and 39 other references.

<div align="right">D. J. HOLLAND</div>

International Meteorological Vocabulary, WMO Tech. Paper No. 91. 10¾ in × 7 in, pp. xvi + 276, Secretariat of the World Meteorological Organization, Geneva, 1966. Price : Sw.F.40.

Among the many valuable achievements of the World Meteorological Organization (WMO), not least is the acceptance by all countries of agreed practices and agreed terminology which have been adopted not only by the national weather services but also for the most part by meteorologists everywhere. This publication, giving the equivalent terms in the four working languages of the Organization, English, French, Spanish and Russian, is therefore likely to be accepted without serious controversy and to be regarded as authoritative. It should be specially valuable to librarians and editors, and as an occasional work of reference it should be available everywhere.

The work is planned in an unexpected way, with the Meteorological Section of the Universal Decimal Classification (UDC) (551·5) providing the structure. In this choice one can detect the influence of the professional librarian, and on the whole it is probably the best that could be devised, as it brings closely related terms into proximity, and with regular use will soon become familiar. The occasional user may, however, feel frustrated if he wishes to check the

meaning of some unfamiliar term in Spanish or Russian. He must first find the term in an alphabetical index for that language, beginning on page 219 or page 231, and so be directed to the appropriate page of the four-language list of terms. Here he will find the English or French equivalent, and a further reference will lead to the correct page in the English or French list of definitions, for only the two languages are used for this purpose. Yet it would not be easy to find a better method, and the details of the UDC given in all four languages form a useful feature in themselves.

The number of terms is something over 2000, similar to that of the Meteorological Glossary of the British Meteorological Office (London, HMSO, 1963), and therefore much less than that of the altogether more comprehensive Glossary of Meteorology published by the American Meteorological Society (Boston, Mass., 1959). The international publication provides only minimum definitions of the terms, and will not therefore serve the purpose of either of the two national glossaries. At the same time, it goes beyond these works in including a number of formal definitions agreed by the WMO or the International Civil Aviation Organization, and having a legal or quasi-legal standing. An Appendix gives the Abridged International Ice Nomenclature with terms and definitions in all four languages.

The standard of printing is excellent, and one feels confident from the list of the names of compilers and referees that the translations have been carefully scrutinized. It was therefore a little disappointing, in checking word by word a two-page sample of definitions (pp. 80–81), to find half a dozen points which are either wrong or at least open to criticism by the punctilious. Constancy of vorticity is not sufficient to define the 'constant absolute vorticity trajectory' as generally understood. The 'circle of inertia', as defined, requires no reference to an 'air particle.' The definition of 'Coriolis force' is an unhappy one. A 'hyperbolic point', of interest in frontogenesis, should refer to the field of deformation : there need be no divergence (the American glossary notwithstanding). The 'equation of motion' as given is not restricted to 'unit mass' of fluid. The 'equation of continuity' is wrongly stated in its second form. The letter f is omitted under 'barotropic vorticity equation'. The definition of 'geostrophic equilibrium' is objectionable without the condition that the horizontal components of the forces are intended. And finally, the last item on the page 'tendency equation' implies that 'advection' is transfer by the horizontal motion, inconsistent with the definition of advection on the same page.

A more cursory examination of the text as a whole shows that my random two-page sample is not representative, but, even so, there is evidently room for further polishing, a conclusion which will be exasperating to the compilers and editors, who through the years of drafting and revising must have spent many tedious hours trying to reconcile opinions, usages and accepted conventional definitions. Knowing, however, that an international group of scientists will sit up half the night disagreeing about a single definition, one can have nothing but unqualified admiration for the World Meteorological Organization in producing this work at all. It is by any standard a remarkable achievement, and fully worth while.

R. C. SUTCLIFFE

AWARDS

L. G. Groves Memorial Prizes and Awards

The L. G. Groves Memorial Prizes and Awards for 1966 were presented by Major K. J. Groves on 10 November 1966 at the Ministry of Defence, Whitehall. The presentation was presided over by Air Marshal Sir Reginald Emson and attended by the Director-General of the Meteorological Office, Dr B. J. Mason.

The Memorial Prize for Meteorology was presented to Dr N. E. Rider, Principal Scientific Officer at the Meteorological Office, Bracknell. For the past five years Dr Rider has been an active leader in the development of Meteorological Office equipment in the Instrument Development Branch and has, throughout this period, contributed much to the modernization of meteorological instruments and to the introduction of automatic methods of observing and recording data. During the past year Dr Rider has contributed significantly to a number of important projects, and, in particular, he has given to the teams of scientists and technicians involved a sense of urgency and of compromise between the ideally possible and the technically practical which has led to the introduction into service of effective new equipment (see Plate III).

The Memorial Prize for Aircraft Safety was won by Squadron Leader K. E. Wills, A.M.I.Mech.E.,A.F.R.Ae.S. The winch hook currently fitted to Wessex aircraft of the Royal Air Force and Royal Navy has proved dangerously unsafe on many occasions. 'D' rings supporting loads have twisted off the winch hook with the risk of injury to personnel and damage to material loads. Squadron Leader Wills has designed and constructed a new hook which operates on the basis of a scissor action. This hook is completely safe in that the design gives total enclosure of load rings once the hook is closed and removal of 'D' rings can only be effected by deliberate opening of the hook unit.

The Meteorological Observer's Award went to Mr B. W. Butler, formerly of the Meteorological Research Flight, Farnborough. Mr Butler has flown some 800 hours with the Flight and has always shown an exceptional degree of skill and resolution in obtaining his observations especially from Canberra aircraft where confined working space and high altitudes cause unusual difficulties. This was emphasized by his devotion to duty and his coolness during unusually dangerous flights to investigate the heights of cumulonimbus tops over Malaya. This example and leadership have played a significant part in the success of investigations undertaken by the Meteorological Research Flight in the last five years (see Plate IV).

Wing Commander J. R. Dowling, M.B.E. D.F.C., A.F.C., who won the Second Memorial Award, was not able to attend the presentation.

The operation of helicopters at night into tactical landing sites has become a pressing operational requirement. Wing Commander Dowling has submitted a design for an approach lighting system which can be effectively constructed by unskilled persons with no requirement for sophisticated equipment. It differs from the 1965 aircraft safety prize-winning entry in that it gives an accurate glide path with an indication of the rate of approach and range. In addition the aid gives a defined hover point, necessary for the completion of successful night landing.

NOTES AND NEWS

Retirement of Mr L. H. Starr

Mr L. H. Starr, M.B.E., retired from the Meteorological Office on 6 November 1966 after over 37 years' service.

Mr Starr joined the Office in April 1929 on transfer from the War Office in which department he had begun his career some six months earlier. Until his secondment for duty in India at the end of 1935, Mr Starr served in Met.O.4, Met.O.2, and at Calshot, Kew and Pembroke Dock. His service in India, which was broken for only a few months, lasted from October 1935 until December 1943. He was appointed a member of the Order of the British Empire whilst serving in India.

On return to this country Mr Starr was posted to Dumfries and in January 1947 to Dunstable where he served in the Napier Shaw Laboratory, in Met.O.2 as a senior forecaster and, from March 1958 until his retirement, as Assistant Director (Observations and Communications). In this capacity he attended many meteorological conferences and meetings in almost every country in the world and became well known and respected by a large number of foreign meteorologists. His keen sense of humour has, on several occasions, enlivened the formal proceedings of international meetings. His frequent overseas visits however, did not include one to Australia, an omission which he is going to rectify in 1967 when Mrs Starr and he will spend a long holiday with their daughter who now lives in Melbourne.

Mr Starr is a keen and skilled horticulturist and was Chairman for many years of the flourishing Horticultural Society of the Meteorological Office, Bracknell. He is also keenly interested in music and was a member of the Meteorological Office Choral Society. It may not be common knowledge that whilst in India he formed a choral society which had the honour of singing before the Viceroy. His numerous friends wish him a long and happy retirement to enjoy his many and varied interests.

V. R. COLES

OBITUARIES

It is with regret that we have to record the deaths of Mr G. C. Milton, (disestablished S.A., Met.O.3) on 24 November 1966, and also that of Mr A. Elliott, (SXO) on 9 December 1966.

HONOUR

The following award was announced in the New Year Honours List, 1967:

M.B.E.

D. McFarlane, Senior Experimental Officer, Royal Air Force, Abingdon.

CONTENTS

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General Meteorological Office, London Road, Bracknell, Berkshire, and marked "for Meteorological Magazine."

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

All inquiries relating to the insertion of advertisements in the Meteorological Magazine should be addressed to the Director of Publications, H.M. Stationery Office, Atlantic House, Holborn Viaduct, London E.C.1. (Telephone: CITy 9876, extn 6098).

The Government accepts no responsibility for any of the statements in the advertisements appearing in this publication, and the inclusion of any particular advertisement is no guarantee that the goods advertised therein have received official approval.